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FOR

ELECTROLESS PLATING SYSTEMS AND METHODS

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ELECTROLESS PLATING SYSTEMS AND METHODS

TECHNICAL FIELD & BACKGROUND

The present invention is related to the field of integrated circuits (IC). More specifically, various aspects of the present invention are related to electroplating electroless plating of wafers, an operation included in most IC fabrication process. As with virtually all other fabrication operations, deposition, planarization, etching, and so forth, the requirements have to be met with virtually no deviation.

BRIEF DESCRIPTION OF THE DRAWINGS

The present invention will be described by way of exemplary embodiments, but not limitations, illustrated in the accompanying drawings in which like references denote similar elements, and in which:

Figure 1 illustrates an electroless plating system, in accordance with one embodiment of the present invention;

Figure 2 illustrates an electroless plating method employing the electroless plating system of **Fig. 1**, in accordance with one embodiment of the present invention;

Figure 3 illustrates another electroless plating system, in accordance with another embodiment of the present invention;

Figure 4 illustrates another electroless plating method employing the electroless plating system of **Fig. 3**, in accordance with another embodiment of the present invention;

Figure 5 illustrates yet another electroless plating system, in accordance with yet another embodiment of the present invention; and

Figure 6 illustrates yet another electroless plating method employing the electroless plating system of **Fig. 5**, in accordance with yet another embodiment of the present invention.

DETAILED DESCRIPTION OF ILLUSTRATIVE EMBODIMENTS

Various aspects of the illustrative embodiments will be described using terms commonly employed by those skilled in the art to convey the substance of their work to others skilled in the art. However, it will be apparent to those skilled in the art that the present invention may be practiced with only some of the described aspects. For purposes of explanation, specific numbers, materials and configurations are set forth in order to provide a thorough understanding of the illustrative embodiments. However, it will be apparent to one skilled in the art that the present invention may be practiced without the specific details. In other instances, well-known features are omitted or simplified in order not to obscure the illustrative embodiments.

Various operations will be described as multiple discrete operations, in turn, in a manner that is most helpful in understanding the present invention, however, the order of description should not be construed to imply that these operations are necessarily order dependent. In particular, these operations need not be performed in the order of presentation.

The phrase "in one embodiment" is used repeatedly. The phrase generally does not refer to the same embodiment, however, it may. The terms "comprising", "having" and "including" are synonymous, unless the context dictates otherwise.

Referring now to **Fig. 1**, wherein a simplified diagram illustrating an electroless plating system, in accordance with one embodiment, is shown. As illustrated, electroless plating system **100** includes point of use (POU) process chamber **102** (hereinafter, simply chamber) and a number of chemical tanks **108** coupled to each other by a piping system **120** as shown. For the embodiment, piping system **120** includes corresponding in-line heaters **114** for tanks **108**. Further, system **100** includes system controller **106** coupled to tanks **108** and in-line heaters **114**.

Chamber **102** is employed to apply a plating solution to wafers. In various embodiments, chamber **102** may be a spray type, a microcell type, a spin on type, or other electroless plating chamber of the like.

For the embodiments, the chemicals employed to form the plating solution are separated pre-heated to an application temperature, and mixed in-line at point **122** of piping system **120** which is substantially just prior to the point of application to a wafer (in chamber **102**). Resultantly, plating solution is anticipated to be more suitable for plating wafer, e,g. containing less particles.

In various embodiments, the plating solution is formed by mixing a metal with a complexing agent, a buffer, a pH adjuster and/or a reducing agent. In various embodiments, the metal may be one of Co, Cu, Ni, Fe, Ag, Au, Pt, Pd and Ru. The complexing agent may be a selected one of a citric acid and EDTA (Ethylenediamine Tetraacetic Acid). The buffer may be a selected one of NH4Cl and a boric acid. The pH adjuster is a selected one of KOH and TMAH (Tetramethylammonium Hydroxide). The reducing agent may be one of DMAB (Dimethylaminobenzaldehyde), hypophosphite, formaldehyde, and glyoxylic acid. The exact composition, including the amount of contribution of each constituent chemical is application dependent.

Tanks **108** are employed to separately hold the metal, and the one or more of the complexing agent, the buffer, the pH adjuster and the reducing agent, separately at room temperature. Tanks **108** may be tanks of any type suitable for the particular chemicals.

Corresponding in-line heaters **114** are employed to separately heat the chemicals to an application temperature. The exact temperature is application dependent. In various embodiments, the temperature is in the range of 30 C – 90 C.

System controller **106** is employed to control the operation of system **100**. In various embodiments, system controller **106** may be a special purpose or general purpose computing device, provided it has the appropriate input/output interfaces for interfacing with the various tanks **108** and heaters **114**. These interfaces may be serial or parallel interfaces of a variety of types.

Figure 2 illustrates an electroless plating method, employing the electroless plating system of **Fig. 1**, in accordance with one embodiment. As illustrated, at **202**, a metal and one or more of a complexing agent, a buffer, a pH adjuster and a reducing agent are separately routed for mixing and application to a wafer. At **204**, the metal and the one or more of a complexing agent, a buffer, a pH adjuster and a reducing agent are separately in-line heated to an application temperature, while they are being separately routed.

Thereafter, at **206**, the heated metal and the heated one or more of a complexing agent, a buffer, a pH adjuster and a reducing agent are in-line mixed substantially just prior to application to the wafer. Finally, at **208**, the near point-of-use mixed plating solution is applied to the wafer.

Referring now to **Fig. 3**, wherein a simplified diagram illustrating another electroless plating system in accordance with another embodiment, is shown. Similar to the embodiment of **Fig. 1**, electroless plating system **300** includes a point of use (POU) process chamber **102** (hereinafter, simply chamber), a number of chemical tanks **108a**, coupled to each other by a piping system **120** as shown. Additionally, electroless plating system **300** includes a number of water and surfactant tanks **108b**, coupled to the earlier enumerated elements as shown. Piping system **120** further includes in-line heater **114** for tanks **108b**. As the embodiment of **Fig. 1**, system **100** also includes system controller **106** coupled to tanks **108a-108b** and in-line heater **114**.

Chamber **102**, tanks **108a** and system controller **106** are employed for substantially the same purposes, and similarly constituted as earlier described for the embodiment of **Fig. 1**, except system controller **106** is also employed to control tanks **108b**.

Tanks **108b** are employed to separately hold de-ionized (DI) water and a surfactant. In various embodiments, the surfactant may be one of RE 610, Triton X100, polyethers, and polyoxyethylne. In alternate embodiments, electroless plating system **300** may be practiced without the use of surfactant.

In-line heaters **114** are employed to heat the mixture of DI water and the surfactant at an application temperature. The exact temperature is application dependent. In various embodiments, the temperature is in the range of 70 C – 100 C.

The heated DI water (with or without surfactant) is employed to heat the pipe segments, as well as to dilute and heat the plating solution. Resultantly, under this embodiment, plating solution is also anticipated to be more suitable for plating wafer, e,g. containing less particles.

Figure 4 illustrates another electroless plating method, employing the electroplating electroless plating system of **Fig. 3** in accordance with one embodiment. As illustrated, at **402**, DI water (optionally mixed with a surfactant) is pre-heated to a predetermined temperature. At **404**, the pre-heated DI water (with or without surfactant) is employed to pre-heat one or more pipeline segments of pipeline system **120**, chamber **102** and a wafer.

Then, at **406**, the chemicals are mixed into an initial relatively more concentrated plating solution, which in turn at **408**, is mixed with the DI water (with or without surfactant) to form the final properly diluted, but heated plating solution. The concentration of the initial plating solution, DI water dilution ratio, and so forth are all application dependent. In various embodiments, 1 to 10 parts of the DI water are mixed with 1 part of the initial more concentrated plating solution.

Finally, at **410**, the diluted, but heated plating solution is applied to the wafer.

Referring now to **Fig. 5**, wherein a simplified diagram illustrating an electroless plating system in accordance with one embodiment is shown. Similar to the embodiment of **Fig. 3**, electroless plating system **500** includes a point of use (POU) process chamber **102** (hereinafter, simply chamber) and a number of chemical, water and surfactant tanks **108a** and **108b**, coupled to each other by a piping system as shown. Additionally, electroless plating system **500** includes electroanalytical subsystem **104**.

The piping system also includes in particular, configurable valve **112** and first and second routes **110a** and **110b** coupling chamber **102** and electroanalytical subsystem **104** to valve **112**. Further, the piping system

includes in-line heaters **114** disposed in between tanks **108b** and valve **112**, i.e. downstream from tanks **108b**, but upstream of valve **112**.

Additionally, electroless plating system **100** includes system controller **106**, coupled to tanks **118a-118b**, electroanalytical system **104**, and heaters **114a-114b** as shown.

Chamber **102**, tanks **108a-108b** and system controller **106** are employed for substantially the same purposes, and similarly constituted as earlier described for the embodiment of **Fig. 1**, except system controller **106** is also employed to cooperate with electroanalytical subsystem **104**.

Electroanalytical subsystem **104** is employed to perform a qualification analysis to qualify the final plating solution before allowing the plating solution to be applied to a wafer in chamber **102**. In various embodiments, electroanalytical subsystem **104** includes a number of modules to perform one or more electroanalysis of reaction kinetics. In various embodiments, electroanalytical subsystem **104** may include one or more electroanalysis modules for performing electroanalysis for adsorption, nucleation, and deposition rates, pH balances, as well as particles generation count.

More specifically, in various embodiments, electroanalytical subsystem **104** may include

- a Quart Crystal Mircobalance (QCM) module to analyze the plating solution for adsorption, nucleation, and deposition rates, based e.g. on frequency changes as a function of weight change,

- an Open Circuit Potential (OCP) module to analyze the plating solution for open circuit potentials, based e.g. on nucleation time,

- a pH meter to analyze the plating solution for pH balance,

- a particle counter to analyze the plating solution for particles.

- An Ultra Violet Visible Spectroscopy (UV-VIS) to analyze the concentrations of metal ions in the solution

Each of these modules may be implemented with any one of a number of these modules available from manufacturers such as, QCM Research of Saddleback Valley of CA, Radiometer Analytical SAS of Lyon, France, and so forth.

In alternate embodiments, electronanalytical subsystem **104** may be implemented with more or fewer electroanalysis modules.

Valve **112** of the piping system is advantageously employed to selectively route the plating solution, via route **110a**, to electroanalytical subsystem **104** for qualification analysis, and via route **110b** to chamber **102** for application, after the plating solution has been qualified by the qualification analysis. In various embodiments, valve **112** may be implemented employing any one of a number of valves of the electronic type. In other embodiments, other controllable or configurable valves may also be employed.

For the illustrated embodiment, system controller **106** is further employed to analyze the results of the qualification analyses performed by electroanalytical subsystem **104**. In various embodiments, system controller **106** compares the results of the electroanalytical analyses, i.e. QCM, OCP and other measurements, with a number of thresholds/limits. In various embodiments, these thresholds and/or limits are pre-provided to system controller **106**. The threshold and/or limits are application dependent, depending on the electroless plating desired for a wafer, and they may be empirically determined.

In various embodiments, system controller **106** stops tanks **108a-108b** from further supplying the plating solution, if not all of the thresholds and limits are met. In other embodiments, system controller **106** may be equipped to adjust

the chemicals, water and/or surfactant supplied by tanks **108a-108b**, and/or the amount of heat supplied by heater **114**, if not all of the thresholds and limits are met, but the failing metrics are within certain tolerance levels. Just like the threshold and limits, the tolerance levels are application dependent, and may be empirically determined.

In alternate embodiments, the plating solution to be qualified may be formed employing tanks **108** and corresponding in-line heaters **114**, configured as shown in **Fig. 3**. Regardless, the embodiment provides a high degree of assurance in achieving the desired quality of electroless plating.

Figure 6 illustrates yet another electroless plating method of the present invention, in accordance with one embodiment. As illustrated, at **602**, the plating solution is first formed (e.g. as earlier described referencing **Fig. 4**). At **604**, the plating solution is first routed for qualification analysis. At **606**, the results of the qualification analysis are examined to determine if the plating solution passes the qualification analysis. If the determination is affirmative, i.e. the plating solution was determined to pass the qualification analysis, the plating solution is allowed to be routed to the application chamber for application onto wafers, **608**. However, if the determination is negative, i.e. the plating solution failed to pass the qualification analysis, the plating solution is rejected, and the electroless plating process is halted for correction.

Conclusion and Epilogue

Thus, it can be seen from the above descriptions, a novel electroless plating system and method have been described. While the present invention has been described in terms of the foregoing embodiments, those skilled in the art will recognize that the invention is not limited to the embodiments described.

The present invention can be practiced with modification and alteration within the spirit and scope of the appended claims. For example, the chemicals may be delivered in bulk in part or in entirety.

Thus, the description is to be regarded as illustrative instead of restrictive on the present invention.